Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	)	GN Docket No. 12-268

COMMENTS OF LIMA COMMUNICATIONS CORPORATION, INDEPENDENCE TELEVISION COMPANY, WAND(TV) PARTNERSHIP, IDAHO INDEPENDENT TELEVISION, INC., AND WEST CENTRAL OHIO BROADCASTING, INC.

Lima Communications Corporation, Independence Television Company, WAND(TV) Partnership, Idaho Independent Television, Inc., and West Central Ohio Broadcasting, Inc. (collectively, "the Block Stations"),[1] by their attorneys and pursuant to Section 1.415(b) of the Commission's rules, hereby file these comments in the above-captioned proceeding to implement the Spectrum Act.[2]

I. INTRODUCTION

The Block Stations are dedicated, long standing broadcasters that intend to continue serving their licensed communities far into the future, and their only interest in this proceeding is that the Commission strictly follow Congress's mandate to preserve a strong and secure over-

[1] The Block Stations are local operating affiliates of Block Communications, Inc., an integrated media company headquartered in Toledo, Ohio, with interests in cable television systems, newspapers, regional cable networks, and several broadcast television stations. Lima Communications Corporation is the licensee of WLIO(TV), Lima, Ohio; Independence Television Company is the licensee of WDRB(TV), Louisville, Kentucky and WMYO, Salem, Indiana; WAND(TV) Partnership is the licensee of WAND(TV), Decatur, Illinois; and Idaho Independent Television is the licensee of KTRV(TV), Nampa-Boise, Idaho. West Central Ohio Broadcasting, Inc. is the licensee of Class A television station WOHL-CD, Lima, Ohio, and low-power stations WLQP-LP, Lima, Ohio, WLMO-LP, Lima, Ohio, and WFND-LP, Findlay, Ohio.

[2] Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, *Notice of Proposed Rulemaking*, GN Docket No. 12-268, FCC 12-118 (rel. Sept. 28, 2012) (the "*NPRM*"); *Order*, DA-1916 (rel. Nov. 29, 2012). *See also* Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, §§ 6402, 6403, 125 Stat. 156 (2012) (the "Spectrum Act").

the-air television system following the incentive auctions and spectrum repack. As broadcasters in several mid-sized markets adjacent to Top-30 markets, the Block Stations have a strong interest in ensuring that the auction and repacking rules absolutely preserve the service provided by television stations that continue broadcasting following the auctions. Successfully fulfilling Congress's vision of the incentive auction outcome requires, at a minimum: (1) a repack of all full-power and Class A television stations that preserves service to every viewer that receives it today; and (2) a plan for replicating service by low-power television and television translator stations that provide important local services in markets where few full-power stations exist. The FCC has no authority to, and must not, conduct incentive auctions unless it meets these preconditions.

The plain language and legislative history of the Spectrum Act demonstrate that Congress was acutely concerned with preserving the over-the-air television system that has served this country well for more than 70 years. That television system, painstakingly built by hundreds of local small businesses dedicated to serving communities large and small across America, remains the most-relied upon source of local news, information, and entertainment available today. Congress directed the FCC to protect the valuable service TV broadcasters provide to every viewer in the country, and the FCC must make its first priority the preservation of the TV broadcasting system. The Spectrum Act gives the Commission authority to reclaim and re-auction some TV broadcast spectrum – but only so much as can be recovered without impairing the over-the-air broadcasting service. Congress did not give the FCC the choice to recover a greater amount at the expense of TV viewers – it must preserve TV service first and only then seek to reallocate spectrum to wireless services.

Developing a blueprint for a repack that complies with the Spectrum Act is a daunting technical undertaking, and the *NPRM* suggests that the Commission may be underestimating the difficulty and complexity of the task. Two of the Block Stations are likely to be required to relocate as part of any FCC-mandated repack of the broadcast spectrum: WMYO(TV) in Salem, Indiana is located on ATSC Channel 51, and WDRB(TV) in Louisville, Kentucky is located on ATSC Channel 49.

Both of these stations are located in the Louisville, Kentucky DMA, which borders the Indianapolis and Cincinnati DMAs, leading to significant spectrum congestion. Based on private analysis of available channels in the market, finding new channels that would permit WDRB(TV) and WMYO(TV) to replicate their service areas and populations would not be practical today. Yet finding those channels – for these stations and others in markets all across the country – will be the FCC's responsibility once the auction is complete. And the Spectrum Act will require that the new channels replicate the service stations' provided on their old channels.

There is emerging evidence, however, that creating interference-free allotments will get much harder if the Commission tries to work with significantly fewer channels than are currently allotted for TV broadcasting. The Block Stations have attached an engineering study demonstrating that closely repacking stations in a smaller swath of spectrum could cause greater interference than would be predicted by current interference models due to distortion products caused by multiple undesired signals. The Spectrum Act directs the FCC to develop its repack plan consistent with OET-69, and the FCC also must take into account other record evidence relevant to whether the repack plan will actually preserve service as Congress intended. Accordingly, the Block Stations urge the Commission to consider the additional interference risks posed by repacking the broadcast system into too small a spectrum band. This analysis must be completed before the Commission sets the amount of spectrum it plans to recover in the incentive auctions and should commence immediately.

II. THE SPECTRUM ACT REQUIRES REPLICATION OF CURRENT OVER-THE-AIR TELEVISION SERVICE.

A. The Plain Language and Legislative History of the Spectrum Act Require Strict Service Replication as the Repack Standard.

The Spectrum Act's plain language explicitly requires the FCC to "make all reasonable efforts" to protect the existing service areas and populations of full-power and Class A television stations in any post-auction station repack.[3] This requirement obligates the FCC to adopt

[3] Spectrum Act at § 6403(b)(2).

interference protection standards that create replication of the current area and population served by each broadcaster. The *NPRM* indicates that the Commission erroneously reads Section 6403 of the Spectrum Act to require only that repack stations serve a reasonable approximation of their current service areas and viewers.[4] In fact, the "reasonable efforts" requirement of the Spectrum Act requires much more – it requires the FCC's repack plan to be reasonably calculated to achieve protection of existing broadcasters' populations and service areas.[5] "Close enough" isn't good enough. A repack plan that from its inception does not seek to protect the current service of as many viewers as possible simply fails the Spectrum Act's standard.

The legislative history of the Spectrum Act also supports the conclusion that Congress didn't just intend to instruct the FCC to <u>try</u> to protect current service areas and populations; rather, Congress meant for the Commission to <u>actually protect</u> those stations. The original discussion draft of the Spectrum Act released by the Republican staff of the House Energy and Commerce Committee in July of 2011 included no provisions for protecting stations' service.[6] But in November 2011, both the Republican and Democratic staffs released revised discussion drafts, with each including language requiring protection of current television service resembling the language that was ultimately adopted in February of 2012.[7] Significantly, the Democratic

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[4] *NPRM* ¶ 105.

[5] *See, e.g., Schrecker v. U.S. Dep't. of Justice*, 349 F.3d 657, 662 (D.C. Cir. 2003) ("reasonable efforts" standard for government agencies under Freedom of Information Act requires a search of records that is "reasonable calculated" to produce responsive records) (citing *Truitt v. Dep't of State*, 897 F.2d 540, 542 (D.C.Cir.1990) *Peters v. National Railroad Passenger Corp.*, 966 F.2d 1483, 1486-87 (1992) ("reasonable efforts" to give notice require that notice be "reasonably calculated" to provide notice) (citing *Mullane v. Central Hanover Bank & Trust Co.*, 339 U.S. 306, 319 (1950)); *see also Leyda v. AlliedSignal, Inc.*, 322 F.3d 199, 208 (2d Cir. 2003) (ERISA regulations' requirement that a party take measures "reasonably calculated" to ensure receipt of material requires "reasonable efforts").

[6] The original Republican committee staff discussion draft of the Spectrum Act provisions released in July 2012 is available at http://www.publicknowledge.org/files/docs/DraftHouse RepublicanSpectrumBill.pdf.

[7] The Democratic committee staff discussion draft released on November 29, 2011 is available at http://democrats.energycommerce.house.gov/sites/default/files/image_uploads/PubSafe_LegText_11.29.11.pdf ("Democratic Discussion Draft"). The revised Republican discussion draft released on November 29, 2011 is available at http://archives.republicans.energycommerce. house.gov/Media/file/Markups/ Telecom/120111/jobsactdiscussiondraft.pdf ("Republican Discussion Draft").

draft of the bill required only that the FCC protect broadcast service areas and populations "to the extent technically feasible,"[8] a loophole which could have allowed the FCC to adopt the less robust protection of broadcasters' service areas and populations proposed in the *NPRM*. The language that was ultimately adopted rejects that loophole, however, in favor of requiring the Commission to protect broadcast service.[9] It is a well-accepted canon of statutory construction that where "statutory language is rejected by a promulgating body, its absence provides an indication that [Congress] did not wish to have the issue considered."[10] Congress's rejection of the Democratic-proposed language investing the FCC with significant repack discretion must be respected in construing the language Congress did adopt, which contains no such discretion.

Thus, both the plain language and the legislative history of the Spectrum Act demonstrate that the FCC must reject the *NPRM*'s conclusion that the Commission must protect only a reasonable approximation of broadcasters' current service areas and populations. Rather, the "reasonable efforts" language of the statute must be interpreted to require the Commission to adopt a repack plan that replicates stations' current service areas and viewers' current level of service from all stations.

B. The Commission Should Develop a Repack Plan Based on Full Service Replication for Full-Power and Class A Television Stations and Maximum Protection for Low-Power Stations Providing Important Local Service.

The Spectrum Act's strict requirement to replicate broadcasters' existing service areas and populations renders many of the Commission's proposed repack policies inconsistent with the statute. Each of the FCC's proposed interference standards for new repack allotments is unacceptable because each would subject TV stations to new interference and viewers to

[8] Democratic Discussion Draft § 302(b)(4)(B) ("To the extent technically feasible and in the public interest, in making a modification of the spectrum usage rights of a television broadcast station licensee under subparagraph (A), the Commission shall make reasonable efforts to — (i) preserve the amount of population covered by the signal of such licensee within the service area of such licensee; and (ii) avoid any substantial increase in harmful interference to the signal of such licensee as a result of the modification.").

[9] *Compare* Republican Discussion Draft § 104(b)(2) with Spectrum Act §6403(b)(2).

[10] Norman J. Singer, Sutherland Statutes and Statutory Construction §48:4 (7th ed.).

diminished service.[11] The FCC simply has no authority to adopt repack standards that will create new interference; the "reasonable efforts" requirement of the statute does not permit it.

In place of these proposals, the FCC should adopt a service replication/no new interference standard for the repack.[12] Consistent with the Spectrum Act, the plan adopted by the Commission should seek to ensure that every station serves at least the same area and population that it serves today and that all viewers maintain access to the same stations they can view now. The model proposed by the Commission that comes closest to meeting this standard is its modified "fixed interference" option, which would limit interference to "replacement interference" that essentially replicates existing interference areas and populations.[13] But the Commission lacks authority to introduce an additional two percent interference from each interfering station into this model.[14] Instead, the Commission should limit the total amount of new interference suffered by stations and viewers to 0.5% or less.[15] The *NPRM* expresses concern that protecting stations and viewers from loss of service may be impossible because doing so would diminish the agency's flexibility in accomplishing the repack.[16] This is not a legitimate concern. The Commission is not authorized to reclaim and re-auction spectrum at any cost. Its authority is limited to auctions that can be conducted while protecting the over-the-air television broadcasting system.

Similarly, the Commission's proposal to exclude all low-power stations from repack protection ignores Congress's manifest interest in protecting the current over-the-air broadcasting service.[17] In markets with few full-power television stations, low-power stations

[11] *NPRM* ¶¶ 98-112.

[12] As described in Section III below, the Commission's repack standards should take account of potential interference beyond that which would be predicted by OET-69 analysis.

[13] *Id.* at ¶ 107.

[14] *Id.* at ¶ 108. Again, introducing a plan that assumes large amounts of new interference simply fails the Spectrum Act's requirements.

[15] *Id.* at ¶103 (noting that in the DTV transition the Commission defined "no new interference" as 0.5% or less).

[16] *Id.*

[17] *Id.* at ¶ 118.

often provide the only in-market network affiliate programming or other important local service. The Commission should act to preserve these stations as part of the repack.

West Central Broadcasting, Inc., operates two low-power stations in the Lima, Ohio DMA, which has only two licensed full-power stations, one of which is an independent station.[18] For many years, Lima viewers had to settle for network-affiliated service provided from adjacent markets, but today WOHL-CD and WLQP-LP provide a local option for ABC programming, and WLMO-LP is a local CBS affiliate. These are valuable local services and they should not be lost simply because the stations operate with low-power facilities.

Consistent with Congress's express desire to protect stations and viewers from service loss, the FCC should fully protect network-affiliated low-power and translator stations and other low-power and translator stations that can demonstrate substantial local service. While the Spectrum Act does not require protection for all low-power and translator stations,[19] it does not prohibit the FCC from protecting those facilities where they provide important local services and strengthen the over-the-air broadcasting system. Moreover, the relatively small number of these stations, with their small service areas, should not greatly complicate the repack process. Thus, the Commission can protect these services at virtually no cost to a successful auction and repack process while vindicating Congress's interest in protecting current over-the-air broadcast service.

III. THE POST-AUCTION REPACK MUST BE BASED ON SOUND ENGINEERING PRINCIPLES, INCLUDING OET-69 AND OTHER AVAILABLE ENGINEERING EVIDENCE.

The FCC's technical standards for the repack must further Congress's goals to protect stations and viewers from lost television service. The Spectrum Act requires the FCC to use OET Bulletin 69 to protect the services provided by full-power and Class A stations.[20] The FCC must recognize, however, that Congress's direction to use OET Bulletin 69 is the minimum

[18] *See* BIA, *Investing in Television 2012* (3d ed.).

[19] Spectrum Act §6403(b)(5).

[20] Spectrum Act §6403(b)(2); *NPRM* ¶ 92.

standard the agency may use. That does not preclude the Commission from considering other technical and engineering evidence that might suggest more stringent standards are necessary to protect over-the-air broadcast service as Congress intended.

Indeed, evidence is emerging that simply using OET Bulletin 69 may not be sufficient to protect existing broadcast service. The Block Stations attach hereto an engineering study produced by Charles W. Rhodes, an experienced broadcast engineer who was Chief Scientist for the Advanced Television Test Center, Inc., which performed much of the early testing on DTV that formed the basis for the DTV Table of Allotments.[21] Mr. Rhodes and fellow engineers Linley F. Gumm and Stanley P. Knight conducted tests on NTIA-approved digital-to-analog converter boxes ("DTA Converters") to determine their ability to maintain reception in an environment with multiple strong undesired UHF signals, an environment likely to resemble the close-quarters stations will experience after the repack. One of the key interference issues they measured was front-end tuner desensitization, and their results have practical importance for most DTV receivers in use because most use the same type of front-end receiver used by the NTIA converter boxes.

The testing conducted by the Rhodes team revealed a number of important interference concerns that must be addressed by the FCC as part of its repack process. In the first place, continued use of the 30 million DTA Converters distributed through the NTIA's coupon program – as much as 20% of the DTV receiving devices in operation today[22] – could be compromised in whole or in part because some of these devices are incapable of adequately tuning channels when there is an undesired signal located at N+14 or N+15[23] while others would become effectively non-functional if Channel 37 is used for TV service.[24] Any spectrum repack must take into

[21] *See* Attachment A.

[22] Charles W. Rhodes, *Testing Interference on UHF Taboo Channels*, TV TECHNOLOGY, January 16, 2013, *available at* http://www.tvtechnology.com/insight/0083/testing-interference-on-uhf-taboo-channels/217257.

[23] In this context "N" is equal to the channel assignment of any desired DTV signal on channels 2-51.

[24] DTA Converters utilize two different processes for converting digital signals to analog. Single Conversion Tuners ("SCTs") down-convert incoming desired signals to an intermediate frequency of

account the effect on consumers who have relied on the NTIA converter box program and consider establishing an allocation taboo at N+14 and N+15 as well as foregoing use of Channel 37.[25]

The Rhodes testing also uncovered potential front-end tuner desensitization by near-adjacent undesired UHF signals and by multiple undesired UHF signals that goes beyond DTA Converters, may impact all DTV receivers, and must be considered in any repack process. This testing showed significant desensitization for a single undesired UHF signal located at N+2 or N+3 to the desired signal. To minimize this desensitization, any station reallocated to N+2 or N+3 channels should be required to collocate its transmitter with the station on Channel N.

In addition, repacking all broadcasters into a smaller band of spectrum will create additional instances where the desired signal must compete with two or more strong UHF signals. Depending on the spacing between the channels, two undesired signals can cause 2nd order distortion products, 2nd harmonics and other intermodulation products, while three or more undesired signals cause further desensitization, more intermodulation products, including Triple Beat interference that increases rapidly as additional undesired signals are received. The FCC's current interference prediction models simply do not account for the desensitization and interference generated by pairs and triplets of channels. When the Commission shrinks the broadcast band, the close channel spacing of stations that will be necessary will increase these interference risks and may lead to widespread DTV receiver failure.

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44 MHz. SCTs lack adequate filtering to reject interference on the Image Frequencies located at N+14 and N+15. Double Conversion Tuners ("DCTs") first up-convert incoming desired signals to an intermediate IF at 1222 MHz where the signal is filtered by a Surface Acoustic Wave ("SAW") filter, amplified, and down-converted to a second IF at 44 MHz. The first IF for DCTs is located at the second harmonic of Channel 37 (611 MHz), and any strong undesired signal on Channel 37 would generate second-order distortion products that cause the converter boxes to fail.

[25] DCTs also showed susceptibility to desensitization interference from pairs of undesired UHF signals located at symmetrical distances from Channel 37 (*e.g.*, Channels 35 and 39 or Channels 17 and 57). If the Commission intends for DCTs to continue providing interference-free viewing following the repack, it must avoid repacking stations on all these channel pairs.

The FCC should conduct additional laboratory testing to determine the extent of the desensitization and other interference probabilities identified by the Rhodes testing. Depending upon the results, the Commission may need to examine the potential need for DTV receiver standards or the reintroduction of UHF channel spacing taboos. In any case, the Rhodes testing shows that current FCC interference models are inadequate to ensure a repack that protects stations' current level of service to viewers across the country.

V. CONCLUSION

For the reasons stated herein, the FCC must adopt rules and deploy its engineering and planning resources with the overriding purpose of fulfilling Congress's mandate to protect existing over-the-air television service to all Americans.

Respectfully submitted,

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/s/

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January 25, 2013

ATTACHMENT

A

Statement of
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Former Chief Scientist of the Advanced Television Test Center
With Respect to Questions Raised in the NPRM
January 25, 2013

History

Historically the FCC has always been concerned with interference between two television signals on different frequencies. One is the existing station on its allotted frequency and the other is a proposed station allotment in the same band to a second entity. That was a non-trivial problem and the FCC had much experience with it even while TV was being developed.

Summary

TV Off-The-Air Reception

The complexity of the problem of interference among television signals is increased by considering what happens when there is more than one potential interfering signal. Two undesired signals can generate distortion products that may fall in the channel to which receivers are tuned causing interference. With analog TV, such interference produced wavy lines on the screen, which could be annoying to viewers. With DTV, interference simply blocks reception; it denies the viewer access to the desired program. Therefore, interference is a far more serious problem for DTV reception. As a result of what I have learned though many years of working with DTV as Chief Scientist of the Advanced Television Test Center ("ATTC") and hands-on research that I have conducted regarding DTV reception, I have formed the opinion that after the FCC re-packs the remaining TV spectrum, there will be much more interference than there is today.

With the advent of the UHF band, which the FCC opened up to TV broadcasting in 1952, the FCC engineers realized that a station on certain channels of the UHF band would cause interference to another station's signal in the UHF band so they invented a set of Taboos which all Consulting Engineers know well. These taboos set distance limits between transmitters on certain pairs of channels to greatly reduce interference. During the analog television era, observance of these taboos successfully limited harmful interference among television stations.

But when the FCC looked at the data concerning DTV – DTV interference that was supplied by the Advanced Television Systems Committee ("ATSC") in 1995, and which was produced by the ATTC, it concluded that the prototype DTV receiver was so effective at rejecting undesired signals, that the UHF Taboos simply did not apply to DTV.

That data was provided to the FCC by the ATTC, under my technical supervision. I was its Chief Scientist over the entire period of its operation, 1988 – 1996. The data formed part of the basis for the Commission's decisions in its *Sixth R&O* in MM Docket No. 97-268.[1] On page A-2 of Appendix A to the *Sixth R&O*, DTV-DTV, the data shows that the ATTC had tested interference from a DTV signal two channels from the (desired) channel to be protected and on page A-3 an undesired signal three channels above or below the desired channel. All other data on page A-3 is marked with an asterisk. That asterisk means that the FCC estimated the value shown.[2]

Therefore, in the FCC Rules, Part 73, the FCC's transmitter-to-transmitter distances to protect against interference are given for Co-Channel and First Adjacent Channel DTV-DTV

[1] In the Matter of Advanced Television Systems and Their Impact Upon the Existing Television Broadcast Service, *Sixth Report and Order*, MM Docket No. 87-268, 12 FCC Rcd 14588 ¶¶ 145 n.265, 189 (rel. Apr. 21, 1997).

[2] *See id.* at Appendix A (attached for convenience).

Interference, but there are no channel spacing limits for DTV transmitters operating on any other channels than N (Co-Channel) and N+/-1 (Adjacent Channels).[3]

Recent Tests

The team for this project included myself, Linley Gumm and Stanley Knight. Mr. Gumm designed Spectrum Analyzers for many years. Mr. Knight designed tuners at RCA.

As engineers with decades of experience in RF engineering, we knew the difficulties in obtaining adequate RF Selectivity to reject undesired signals in the UHF Band, 470-890 MHz (1952 limits). To measure the real-world effectiveness of DTV receivers at rejecting undesired signals, we carried out tests of 26 DTV Converter Boxes that had been approved by the NTIA in 2008 for the NTIA Coupon Program. These DTV Converter boxes are small, were readily obtainable, and produced negligible heat. These were important considerations as we planned to test all units simultaneously, something that, to our knowledge, had never been done before.

We compiled our research in a presentation to the ICCE 2013 conference, a copy of which is attached.[4] The first several graphics in our presentation show our test set-up and the means by which we monitored reception of both the audio and video outputs of these Converter Boxes.

We knew that at the FCC's laboratory, Senior Engineer Steve Martin had measured the robustness of some 115 models of such converter boxes that subsequently were approved by the NTIA for its Coupon Program.[5] While Mr. Martin reported the critical D/U ratio, we report the desensitization of the median Converter. This is the increase in minimum usable signal power

[3] *See* 47 C.F.R. § 73.623(d).
[4] Presentation entitled, "Protection Ratios for ATSC Digital TV Receivers", ICCE, January 13, 2013 by Charles W. Rhodes, Life Fellow in IEEE; Linley F. Gumm, Life Senior, IEEE and Stanley P. Knight.
[5] Ref. S. Martin, in *Transactions on Broadcasting*, Dec. 2010.

required with the stated interference over the noise limited minimum usable sensitivity. We measured Dmin both with and without the interference. Mr. Knight used our data to compute the median values. This gives the desensitization for 50% of our units. Mr. Knight also computed the 1 Sigma variance. Adding the 1 Sigma variance to the median gives us the performance for the best 84% of these units. This is quite similar to the FCC notion of measuring the effect of interference for the best 90% of locations. We have both the median and the 1 Sigma variance values in our records. Therefore our data could be used for any percentage of units such as what the FCC uses, 90%.[6]

We learned early on that the threshold of acquisition signal power for the video and accompanying audio may be different – so we monitored both. Our test results reflect the level at which both audio and video were obtained free of artifacts.

Linley Gumm and I took these measurements working as a team over many months. At the start of each session, we measured the noise-limited minimum usable DTV signal power (Dmin) value for each unit. Those records demonstrate that we knew that none of our units had changed in performance and that our RF Test Bed had not changed in its performance either.

Measurement Results

There are two categories of tuners in these converter boxes: Single Conversion Tuners (SCT) in which the desired DTV signal (on air-Channel N 2-69) is down-converted to the Intermediate Frequency of 44 MHz. Double Conversion Tuners ("DCT") have a different approach in which the desired on-air signal (on Channel N) is up-converted to the 1st IF

[6] All data is available upon request to interested parties.

frequency where it is filtered by a Surface Acoustic Wave Filter ("SAW") which rejects nearly all undesired signals other than those on Channels N+/- 1, 2, and perhaps 3. The Desired DTV signal is then amplified and then down-converted to the 2nd IF (44 MHz). It is then filtered by the 2nd IF Filter to further attenuate undesired signals before they are demodulated.

Single conversion tuners mass produced at a cost consumers are willing and able to pay cannot provide enough interference rejection at the "*Image Frequencies.*" These are channels N+14 and N+15. This means that a strong signal on either Channel N+14 or N+15 can cause interference to reception of a signal on Channel N. This problem is addressed by designers of SCT tuners by providing a Tracking Filter. However, tracking filters cannot attenuate these undesired signals as effectively as a SAW filter, which works only on one frequency (the 1st IF frequency) of DCT tuners. The converter boxes we tested showed that DCT tuners attenuate undesired signals such as N+14 and N+15 with the SAW Filter at the 1st IF.

We found that all Converter Boxes that we tested have a 1st IF centered at 1222 MHz. This was chosen because it is the second harmonic of Channel 37 (611 MHz). This may be the only reasonable frequency with today's-state-of-the-art above the UHF TV Broadcast Band. Any strong signal on Channel 37 would generate second-order distortion products, including the 2nd harmonic which is centered on 1222 MHz. There are no strong signals on Channel 37 since it is not allocated for TV.

We observed the interference caused by a strong signal on Channel 37 by generating an ATSC signal on that channel and adding it to a desired signal on another channel. This Undesired signal on Channel 37 caused reception to fail on all of the tested converter boxes that

include DCT tuners. None of the converter boxes with a SCT failed this test.[7] Until now, this potential problem with Channel 37 has not emerged because that channel currently is not allocated for broadcasting anywhere.[8] However, the FCC's *NPRM* in its incentive auction proceeding, *see* FCC 12-118 (Oct. 2, 2012) par. 122, indicates that the FCC is considering re-locating the Radio Astronomy and Medical Telemetry on Channel 37 to new spectrum *and that Channel 37 might be used for TV broadcasting in the future.* Such an action would create severe interference on all DTV Converter Boxes which have a DCT whose 1st IF is the second harmonic of Channel 37. It would not affect DTV reception by other DTV receiving devices.

New Potential Interference Scenario

We have discovered another interference problem unique to DTV receiving devices of the DCT class whose 1st IF = 1222 MHz.

Regardless of the above possibility of re-allocating Channel 37 to broadcast, consider that two strong signals on any pair of channels symmetrical around Channel 37 (611 MHz) can generate a second order distortion product which is the sum of the two Undesired signal frequencies, or of their channel numbers. We tested two channel pairs: 37-2 and 37 +2 as an example of a symmetrical pair close to Channel 37 and another symmetrical channel pair 37 – 20 and 37+20. In this case, one U signal was on Channel 17 and the other on Channel 57. Those results are plotted as our Third Result on Slide 12 of the attached ICCE Presentation. In each case, the power per channel is shown. What is unique about this interference mechanism is that every desired signal is up-converted to 1222 MHz by these Double Conversion Tuners and so is the sum frequency of the two undesired signals. For example, two U signals on Channels 35 &

[7] Steve Martin had reported finding this in the above reference. *See* n.7, *supra*.
[8] *See id.*

39 at – 23 dBm each – would desensitize the median receiver by about 10 dB. This graphic shows the median de-sense + 1 Standard Deviation = 14 dB. This means that about 84% of the units we tested will operate if the Desired signal received is more than 14 dB above the unit's noise floor (- 85 dBm is a typical DTV receiver noise floor). *This interference mechanism is unique to those DTV receiving devices whose 1st IF = 1222 MHz. The author knows of no DCT converter boxes with a 1st IF set to a frequency other than 1222 MHz.*

Slide # 8 of the ICCE Presentation shows our first Result. Here we compared the desensitization of Converter Boxes with a Single Conversion Tuners with those with a Double Conversion Tuner.

First, for one U on Channel N+2, the desensitization by the tuner of the median DCT unit is 24 dB, while for the SCT units, it is 18 dB. Neither level of desensitization should be considered acceptable, so any station re-allocated to N+/-2 should be required to co-site its transmitter with that of the station on Channel N. This is probably true for N+/-3 also.

Note also that the DCT units show a peak desensitization of 12 dB when the U signal is on Channel N+5. The cause of this is not known to the author. For a U signal on Channel N+9, we see that the DCT median is above 15 dB of desensitization. We do know the reason for this. We used Channel 28 for our desired signal. That placed the U signal on Channel 37 with the result of extreme desensitization, as discussed above. Conversely, the median desensitization is minimal for the SCT units for a U signal on Channel 6, or 9, or 12 or 16. However, the desensitization of the SCT units is 13 dB for the two *Image Frequency Channels N+14 and N+15. The DCT outperform the SCT units for Image Rejection, Channels N+14 and N+15.*

Slide 9 shows that the desensitization for a U signal below the D signal N-2 to N-8 is similar to what we found in Slide 8 for U channels above the D channel. Our fourth Result is shown in Slide 14, where we compared the effect of a pair of U signals separated by K for SCT vs. DCT Tuners. The desensitization is virtually independent of the separation (K) for DCT tuners, vs. a large degree of change in desensitization for the SCT tuners. SCT units have a significant performance advantage over DCT units for most interference mechanisms except for Image Frequency Interference.

So far, we have shown the desensitization caused by one and by two undesired signals. There are instances now where there are triplets of strong U signals and a weak Desired Signal. This is likely to become more common after re-packing (author's opinion).

Third Order Distortion Products

Non-Linearity

Third Order non-linearity in the analog front-end (tuner) of DTV receivers becomes significant as an interference mechanism where there are three or more strong signals. First, there are the Third Harmonics of F1, F2, and F3. Second there are intermodulation products of the form 2F1 +/- F2, 2F2 +/- F1,

2F2 +/- F3, 2F3 +/- F2 and

2F3 +/- F1, 2F1 +/- F 3.

For example consider U signals on Channels 25 and 30:

2*25 -30 = 20

A third order distortion product of Channels 25 & 30 falls in Channel 20, and

$$2*25 + 30 = \underline{80}$$

Channel 80 is no longer a TV channel, but this third order distortion product might cause interference to services on former Channel 80.

Triple Beats

Now we present the third order distortion product called Triple Beats:

They are

$$F1 + F2 – F3 \ \&$$

$$F2 + F3 – F1 \ \&$$

$$F3 + F1 - F2$$

For example, three undesired signals (a triplet) could be on Channel s 24, 28, and 35. They would generate interference centered on channel;

$$24 + 28 – 35 = 17$$

$$28 + 35 – 24 = 39$$

$$35 + 24 – 28 = 31$$

This Triplet can cause interference to reception of Channels 17, 39, and 31.

Assuming that the power of each U signal is equal, the power of each Triple Beat is 4 dB greater than for each third order intermodulation product.

Finally, the number of Triple Beats increases with the number of U signals exponentially, not linearly.

With 1 U, there is desensitization only.

With two U, there are 2nd order distortion products; 2nd harmonics and intermodulation products.

With three U, there is even more desensitization, and more intermodulation products, and also Triple Beats.

With more than 3 U, the number of triple beats rapidly increases. For example:

With four	U, the number of triple beats =	12
With five	U,	= 30
With six	U,	= 60
With seven	U,	= 102
With eight	U,	= 182
With nine	U	= 262

It is clear that Triple Beats are the dominant third order distortion products where there are more than three U signals as may become a common situation after repacking of the UHF band.

I believe that the FCC should consider the interference that will be generated by pairs and Triplets of signals. It has never done so in the past.

Many of these third order distortion products will not fall in a desired channel, but the number that fall in a desired channel is expected to increase after repacking.

There are two possibilities: One U signal is on Channel (N + K) and the other is on Channel (N + 2K), in which case the IM products fall principally in Channels N and (N + 3K). K is any integer, positive or negative. Tests by Mr. Steve Martin of the FCC Laboratory extended for K up to +/-10.[9] In each case, reception of the signal on Channel N and also on N+3K suffered desensitization. If the receiver were tuned to N+/-1, or to (N+3K) +/- 1, there would be less desensitization but it will still be there. The other possibility is where these U channels are not related in this manner. In other words, the value of K differs between the two U channels.

Mitigation of Interference after Repacking

1. **Our test results show the extent to which desensitization results from the presence of undesired signals as they affect DTV reception on NTIA Approved Converter Boxes.**
2. **They also have shown that the NTIA approved Converter Boxes with a DCT tuner are more susceptible to interference that the NTIA approved Converter Boxes with a SCT tuner.**

In the interest of spectral efficiency, the FCC should consider compensating owners of NTIA approved Converter boxes that fail after repacking. In this way, the repacking can

[9] *See* n.7, *supra*.

be based upon the known interference rejection of Single Conversion Converter boxes. If this is done the compensation should only be applied to the purchase of Converter Boxes which do not have a 1st IF at 1222 MHz and which do have improved Image Rejection at least equal to the performance we have measured for Double Conversion Tuners with respect to Image Channels N+14 and N+15.based on our test results. If this is not done, re-allocating Channel 37 should not be considered.

3. **Our test results could serve either to justify additional laboratory testing of <u>modern</u> DTV receivers or as the basis for determining the maximum desensitization that would result from each scheme for re-allocating the remaining UHF TV spectrum. I believe that most DTV receivers in the market today have a "tuner-on-chip" (an integrated circuit tuner) with an IF frequency much lower than 44 MHz. Such tuners were not used in products marketed before 2009 (after the Converter Box Program ended) and we have NOT tested DTV receivers with these modern tuners.**
4. **Channels such as N+1, 2, 3 and where possible, Channel 4 relative to Channel N, (the incumbent station) in the repacked spectrum, should only be allowed if they can be co-sited with the incumbent station to protect it against interference.**
5. **The dominant interference mechanism has been shown to be due to multiple U signals of the form (N+K), and (N+2K) with K at least up to +/- 10.**

As K increases, the desensitization decreases so high K values are better than low values of K.

This suggests a priority scheme to mitigate interference:

i. Allow Channel N+16, disallow Channel N+8. Allow Channel N-16, disallow Channel N-8.

ii. Allow Channel N+12, disallow Channel N+6. Allow Channel N-12, disallow Channel N-6.

iii. Allow Channel N+10, disallow Channel N+5. Allow Channel N-10, disallow Channel N-5.

iv. Allow Channel N+ 8, disallow Channel N+4. Allow Channel N-8 disallow Channel N-4.

v. Channels N+/-2, +.-3 and +/-4 should only be allowed if their transmitters are to be co-sited.

vi. Whenever possible, disallow both Channels N+14 and N+15 or require the transmitters to be co-sited with Channel N.

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APPENDIX A
TECHNICAL DATA

I. System Independent Planning Factors
Recommended by the Advisory Committee

Planning Factor	Low VHF	High VHF	UHF
Geometric mean frequency (MHz)	69	194	615
Dipole factor (dBm-dBu) dB (K_d)	-111.8	-120.8	-130.8
Thermal noise (dBm) (N_t)	-106.2	-106.2	-106.2
Antenna Gain (dB) (G)	4	6	10
Downlead line loss for 50 ft. (15 m.) of coax (dB) (L)	1	2	4
Front-to-back ratio (dB) (ratio of forward gain to maximum response over rear 180°	10*	12*	14*
Receiver noise figure (dB) (N_R)	10	10	7
Time probability factor for 90% availability (dB) (dT)	**	**	**
Location probability for (dL) 50% availability (dB)	0	0	0

* For the receiving antenna manufacturer's objectives the values are 14, 16, and 20.

** The time probability factor is defined as the difference F(50,10) minus F(50,50), where these two values are determined from the FCC charts in Section 73.699. This factor is a function of the distance between the transmitting and receiving antennas.

See "Fifth Interim Report of the Planning Subcommittee of the FCC Advisory Committee on Advanced Television Service," March, 1992

II. ATSC DTV System Performance Capabilities

See "Final Technical Report," prepared by the Technical Subgroup of the FCC Advisory Committee on Advanced Television Service, October 30, 1995. The values tabulated are the results of tests of the Grand Alliance system, except those marked with an asterisk. Estimates marked with "*" were made for the purpose of evaluating service and interference. Measurement data for these factors were not taken for the Grand Alliance DTV system. These estimates are based on measurements of the four DTV systems that preceded the Grand Alliance system.

Parameter	Measured Value (dB)
Carrier-to-Noise Ratio	+15.19
Co-channel D/U Ratio	
DTV-into-NTSC	+34.44
NTSC-into-DTV	+1.81
DTV-into-DTV	+15.27
Adjacent D/U Ratio	
Lower DTV-into-NTSC	-17.43
Upper DTV-into-NTSC	-11.95
Lower NTSC-into-DTV	-47.73
Upper NTSC-into-DTV	-48.71
Lower DTV-into-DTV	-41.98
Upper DTV-into-DTV	-43.17
Taboo D/U Ratio, DTV-into-NTSC	
N-2	-23.73
N+2	-27.93
N-3	-29.73
N+3	-34.13
N-4	-34.00 *
N+4	-24.96
N-7	-35.00 *
N+7	-43.00 *
N-8	-31.62
N+8	-43.22
N+14	-33.38
N+15	-30.58
Taboo D/U Ratio, NTSC-into-DTV	
N-2	-62.45
N+2	-59.86

N-3	<	-61.79
N+3	<	-62.49
N-4		-58.00 *

Taboo D/U Ratio, NTSC-into-DTV (continued)

N+4		-58.00 *
N-7		-58.00 *
N+7		-58.00 *
N-8		-58.00 *
N+8		-58.00 *
N+14		-58.00 *
N+15		-58.00 *

Taboo D/U Ratio, DTV-into-DTV

N-2		-60.52
N+2		-59.13
N-3	<	-60.61
N+3	<	-61.53
N-4		-58.00 *
N+4		-62.00 *
N-7		-63.00 *
N+7		-63.00 *
N-8		-63.00 *
N+8		-63.00 *
N+14		-63.00 *
N+15		-63.00 *

III. Noise-Limited Service

Based on the above planning factors and the C/N performance of the ATSC DTV System, the noise-limited field strength levels for DTV service are:

Low VHF Channels (channels 2-6)-	28 dBuV/m
High VHF Channels (channels 7-13)-	36 dBuV/m
UHF Channels (channels 14-69)-	41 dBuV/m

Protection Ratios for ATSC Digital TV Receivers
ICCE, January 13, 2013

BY

CHARLES W. RHODES, LIFE FELLOW, IEEE, LINLEY F. GUMM, LIFE SENIOR, IEEE, AND STANLEY P. KNIGHT, LIFE MEMBER, IEEE

PRESENTED BY DR. UWE KRAUS, FELLOW, IEEE

The Investigation

- Measurement of Noise-Limited Sensitivity of 26 NTIA Approved ATSC Converters.
- Measure the Threshold Desired Signal Power (D) with a Known Undesired Signal power (U).
- Compute the Median values of Useful D power or 50% of units under test.
- Compute the Median plus One Standard Deviation for which 84% of units tested work.

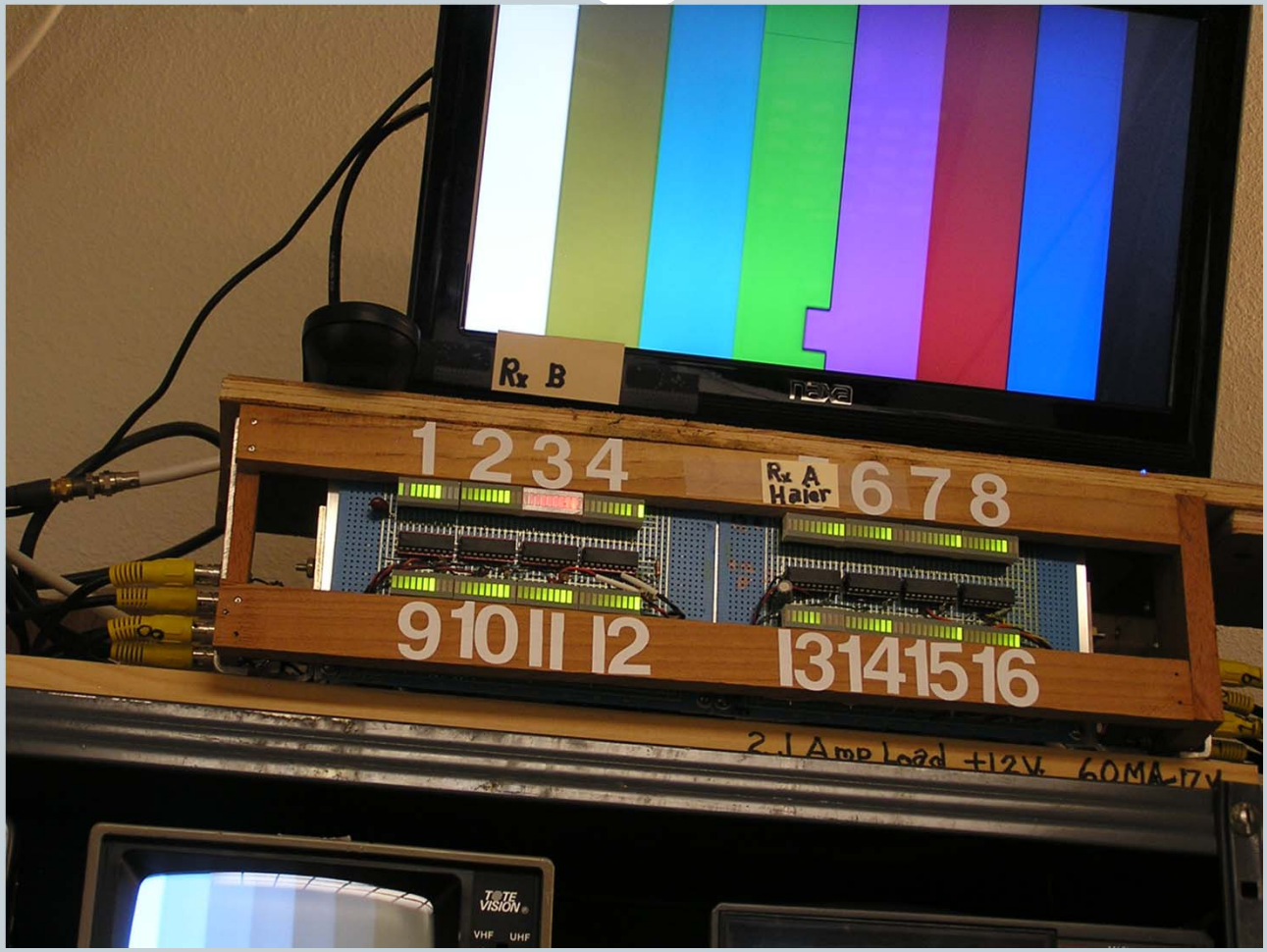
Technique

- Professional Grade ATSC Signal Generators used.
- Simultaneous Video Displays on 26 small monitors.
- Audio continuity monitored on Visual bar graph indicators.
- Desired Signal Power increased in 0.5 dB steps to find Threshold of Acquisition for both video and audio.

Laboratory Instrumentation

Bank of 26 Monitors

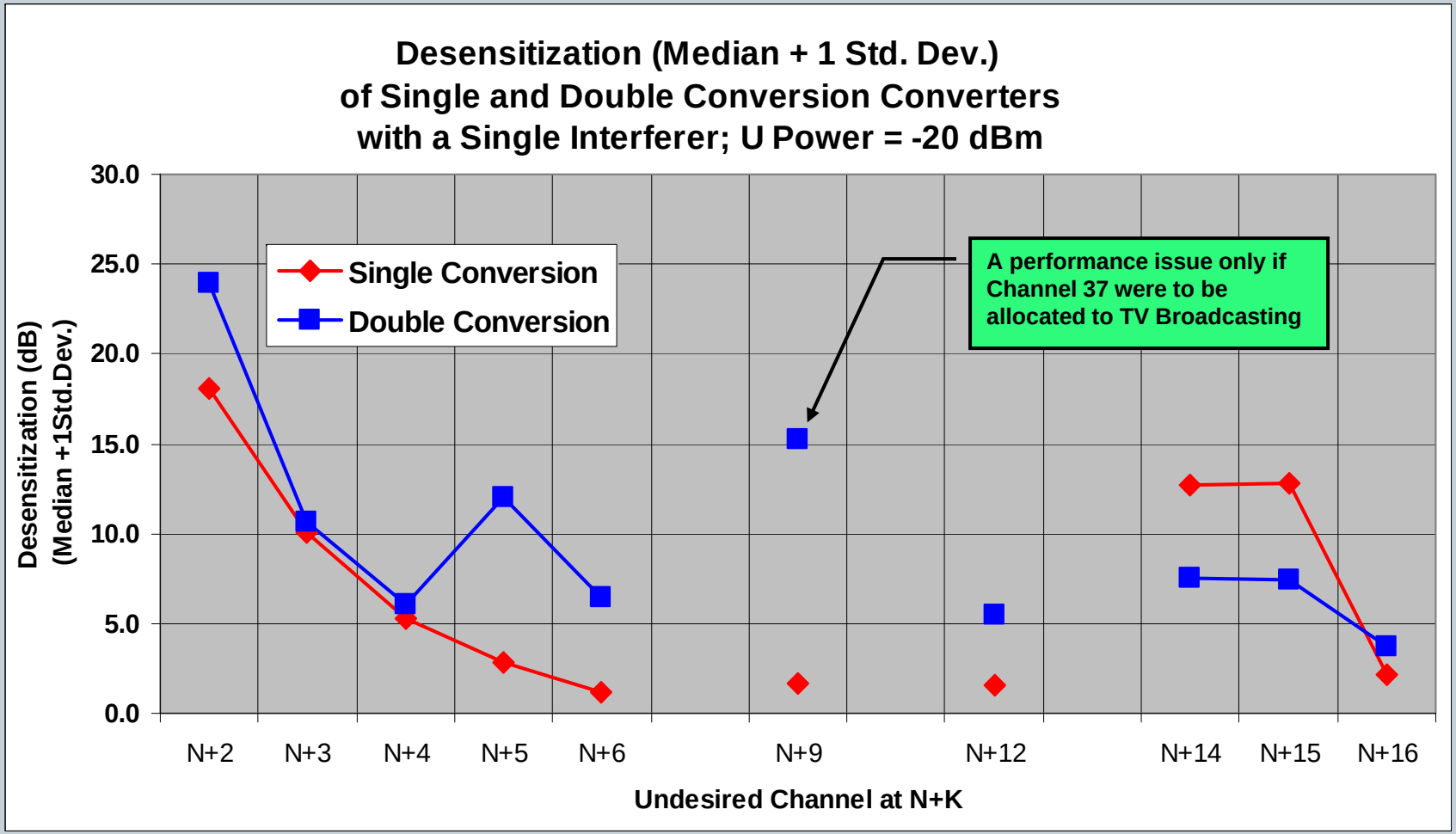
Visual VU Monitors & a DTV Rx



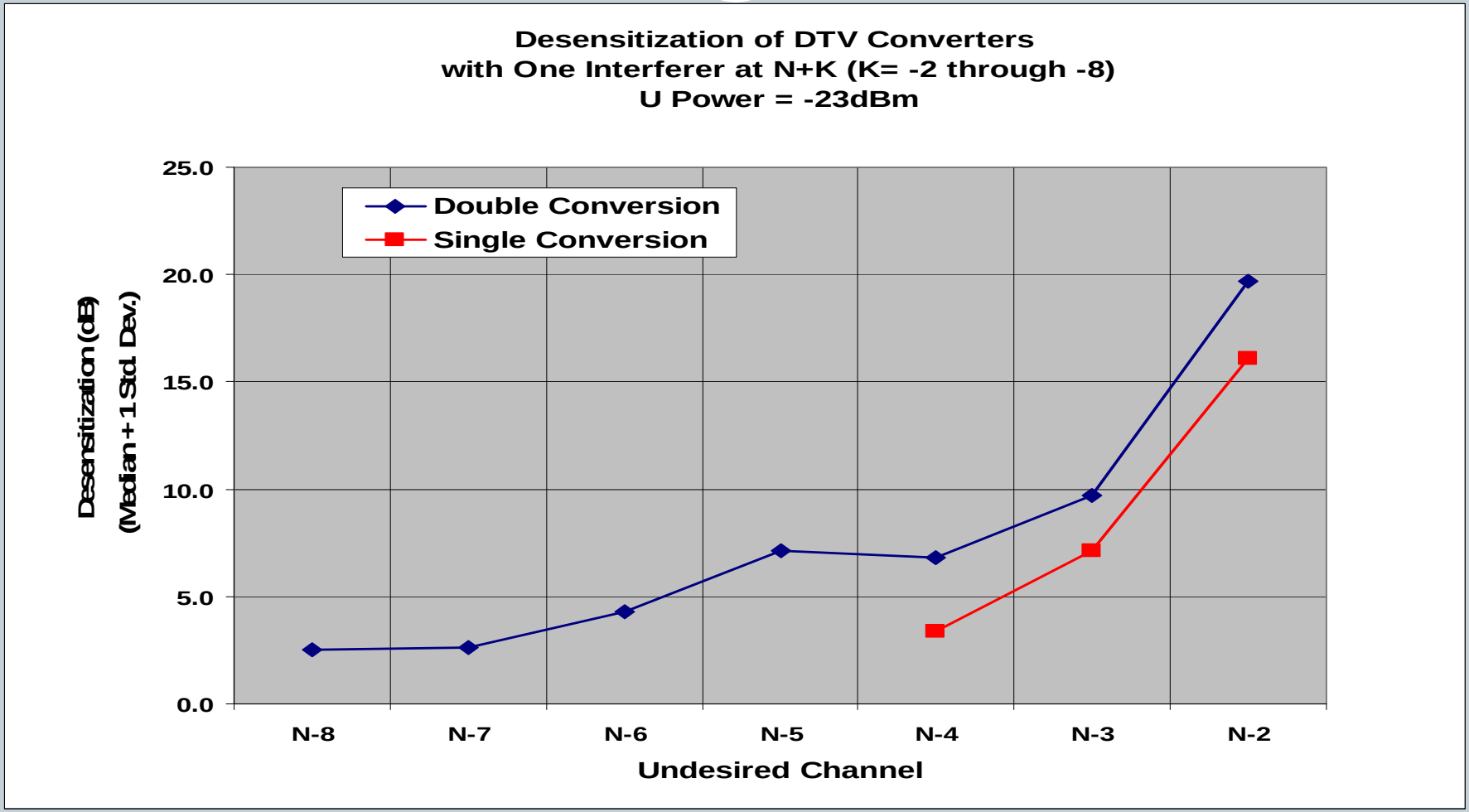
Findings

- Interference from a single U signal 2 to 16 channels offset from the D signal results in loss of reception at D/U ratios well below those anticipated by the FCC (-60 dB).
- D and U Powers track.
- D/U Protection Ratios are nearly constant over the tested range of U power -11 to -41 dBm. This shows the system is linear.
- Desensitization of receivers is a directly measurable parameter. Desense = Min. usable signal with interference minus noise limited sensitivity.
- Single Conversion and Double Conversion tuners behave differently.

First Results



Second Result



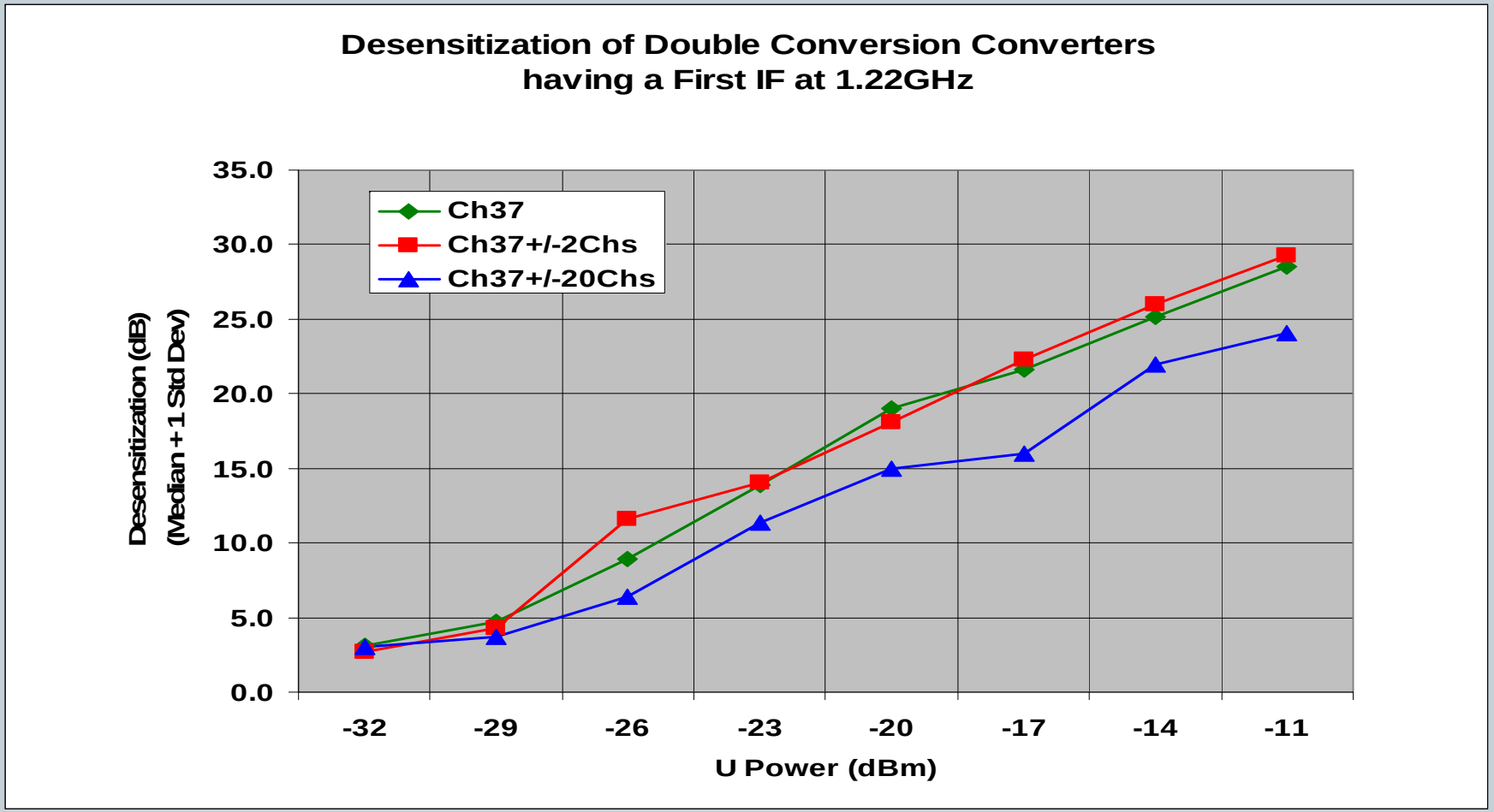
Findings – continued

- Interference differs between the four units known to have Double Conversion Tuners, 1222 MHz 1st IF and 22 units with a Single Conversion Tuner.
- The Double Conversion tuners with a 1st IF: 1222 MHz are sensitive to a U signal on channel 37 (611 MHz). Channel 37 has never been allocated to any broadcaster.
- Double Conversion Tuners excel in Image Frequency Rejection.

Examples Tested

- These Double Conversion tuners are also sensitive to a pair of ATSC Signals on channels above and below channel 37 by the same offset.
- Channels 35 & 39 (37 +/-2) and
- Channels 17 & 57 (37 +/-20)

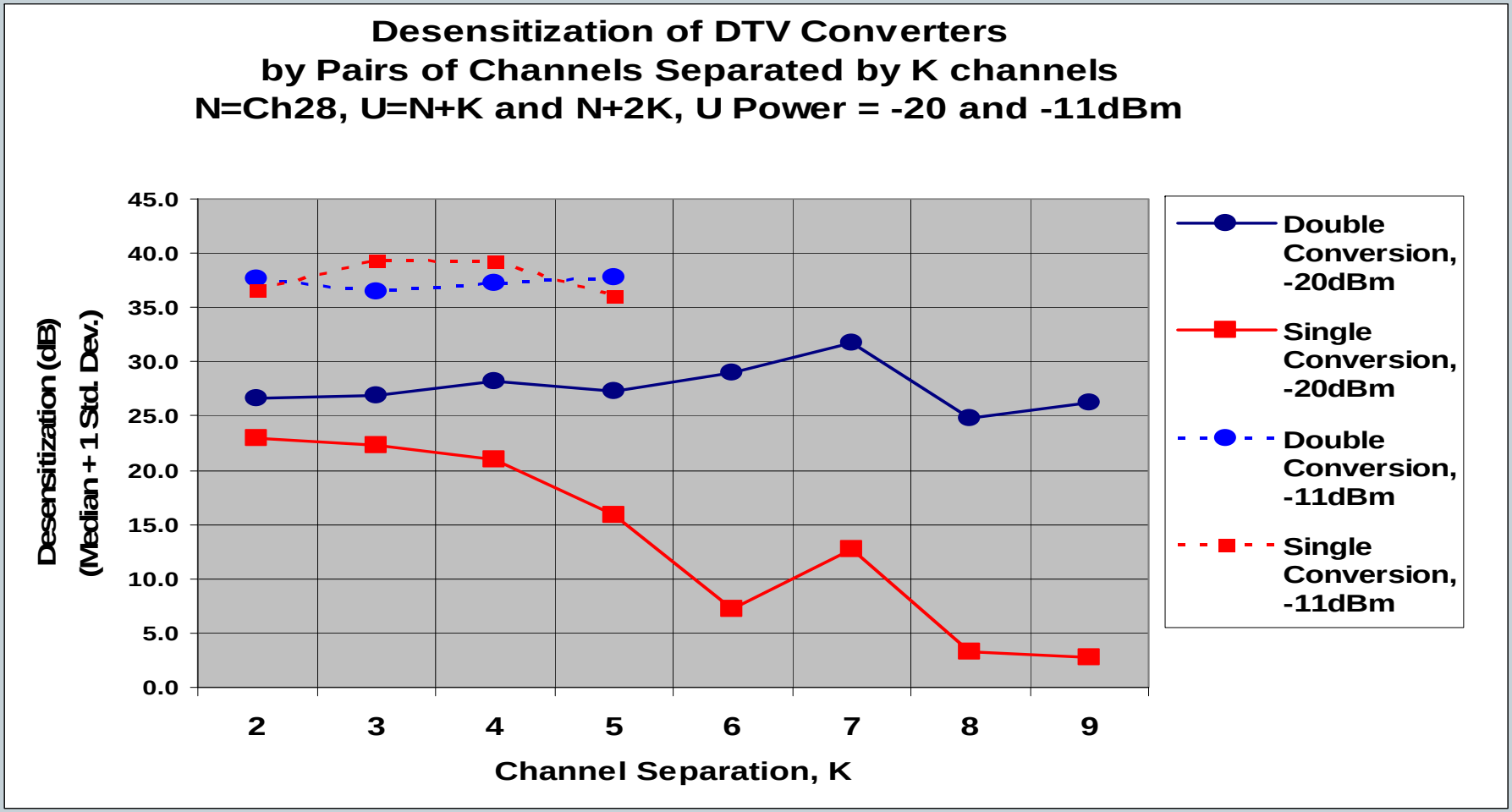
Third Result



Interference from Certain Pairs of Channels

- This is the only non-linear distortion mechanism found in Converter Boxes.
- This is the dominant interference mechanism.
- Note the extreme desensitization of DCT offset 2-9 channels.
- Less desensitization with SCT.

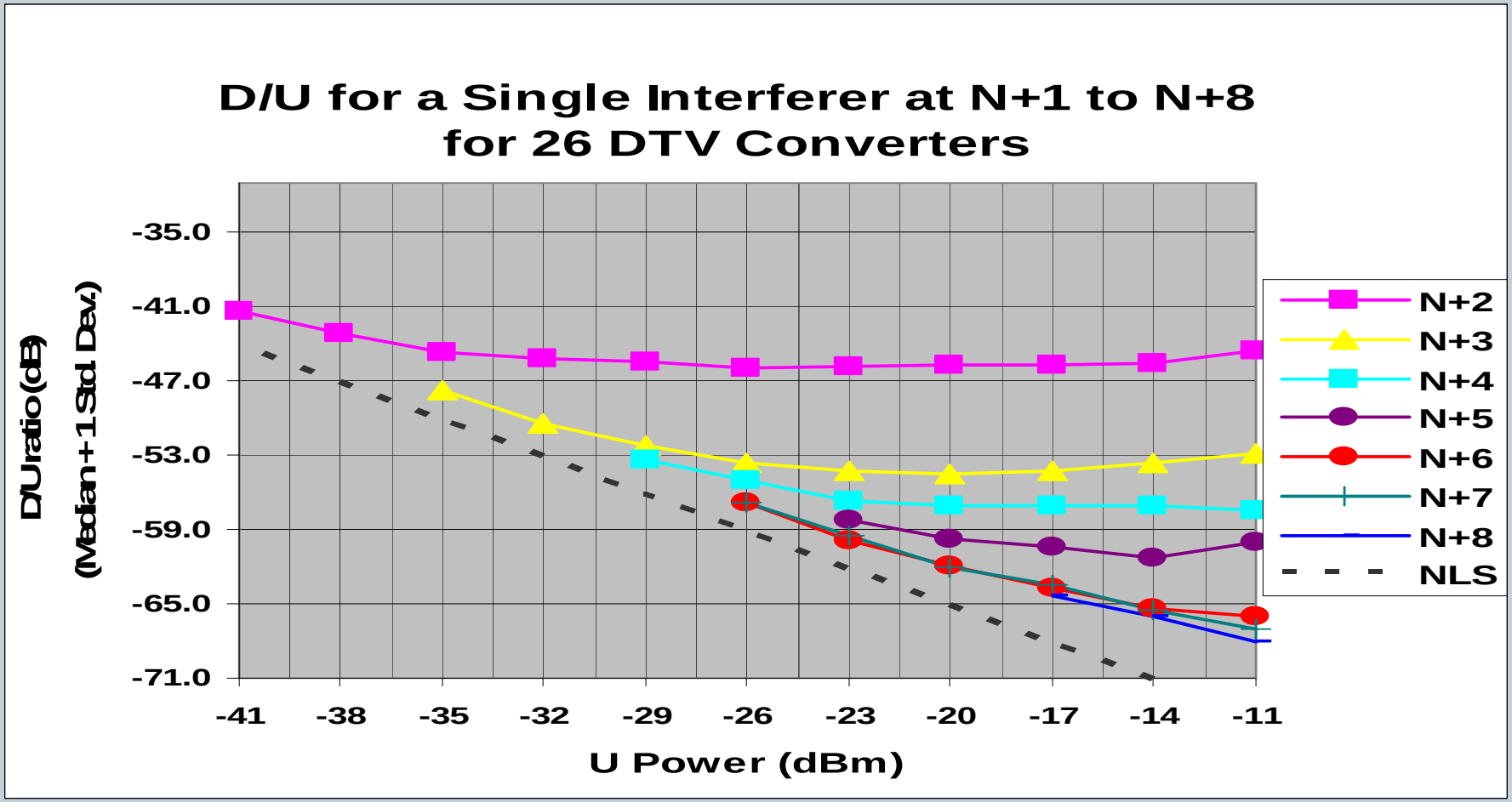
Fourth Result



D/U Ratios

- The ratio is almost constant over the range of U signal power because of Wideband RF AGC converter boxes.
- At large D-U channel offsets the D/U approaches the noise-limited sensitivity of the unit.
- A useful tool for the planners of DTV Service.

Last Result


D/U for a Single Interferer at N+1 to N+8
for 26 DTV Converters
D/U ratio (dB)
(Median+1Std Dev)
-35.0
-41.0
-47.0
-53.0
-59.0
-65.0
-71.0
-41
-38
-35
-32
-29
-26
-23
-20
-17
-14
-11
U Power (dBm)
N+2
N+3
N+4
N+5
N+6
N+7
N+8
NLS

Conclusions

- With further reduction in the UHF TV band the desensitization of some DTV receivers due to new interference will result in loss of service unless the FCC takes into account the substantially lower D/U ratios measured on DTV Converter boxes and likely to also apply to DTV receivers.

- Receivers with better rejection of interference from formerly UHF Taboo Channels will soon be needed after the FCC repacks the UHF TV spectrum.

Conclusions - continued

- The FCC has indicated that it will eventually re-allocate 500 MHz of Spectrum to Broadband. Interference between Broadband and DTV signals is already known in the 700 MHz Band and expected in the 600 MHz band.

- Some of this additional Spectrum may be broadcast spectrum.